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(54) Abstract Title
Locating transmitter

(57) A system for locating an object (10) which produces identifying signals such as an aircraft SSR transponder comprises a plurality of receiver sites (22, 24, 26, 28) arranged in an array (20) for receiving signals from the object (10) and for receiving a common time reference in the form signals received from a global navigation system (50). The array (20) comprises a reference receiver site (22) and three auxiliary receiver sites (24, 26, 28), the auxiliary sites being connected to the reference site by data links (34, 36, 38). Each receiver site (22, 24, 26, 28) receives signals (42, 44, 46, 48) from the object (10) and timing control signals (52, 54, 56, 58) from a global navigation system (50). Each site determines a time difference between the receipt of the object signals and the timing signals, the auxiliary sites (24, 26, 28) providing data signals on data links (34, 36, 38) to the reference site (22) where the location of the object (10) is determined.

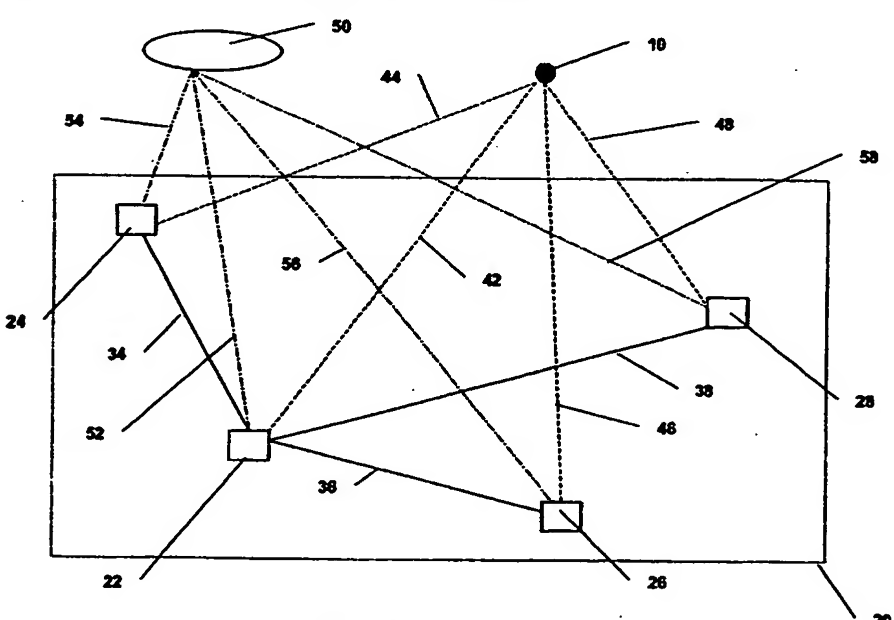

Fig. 1

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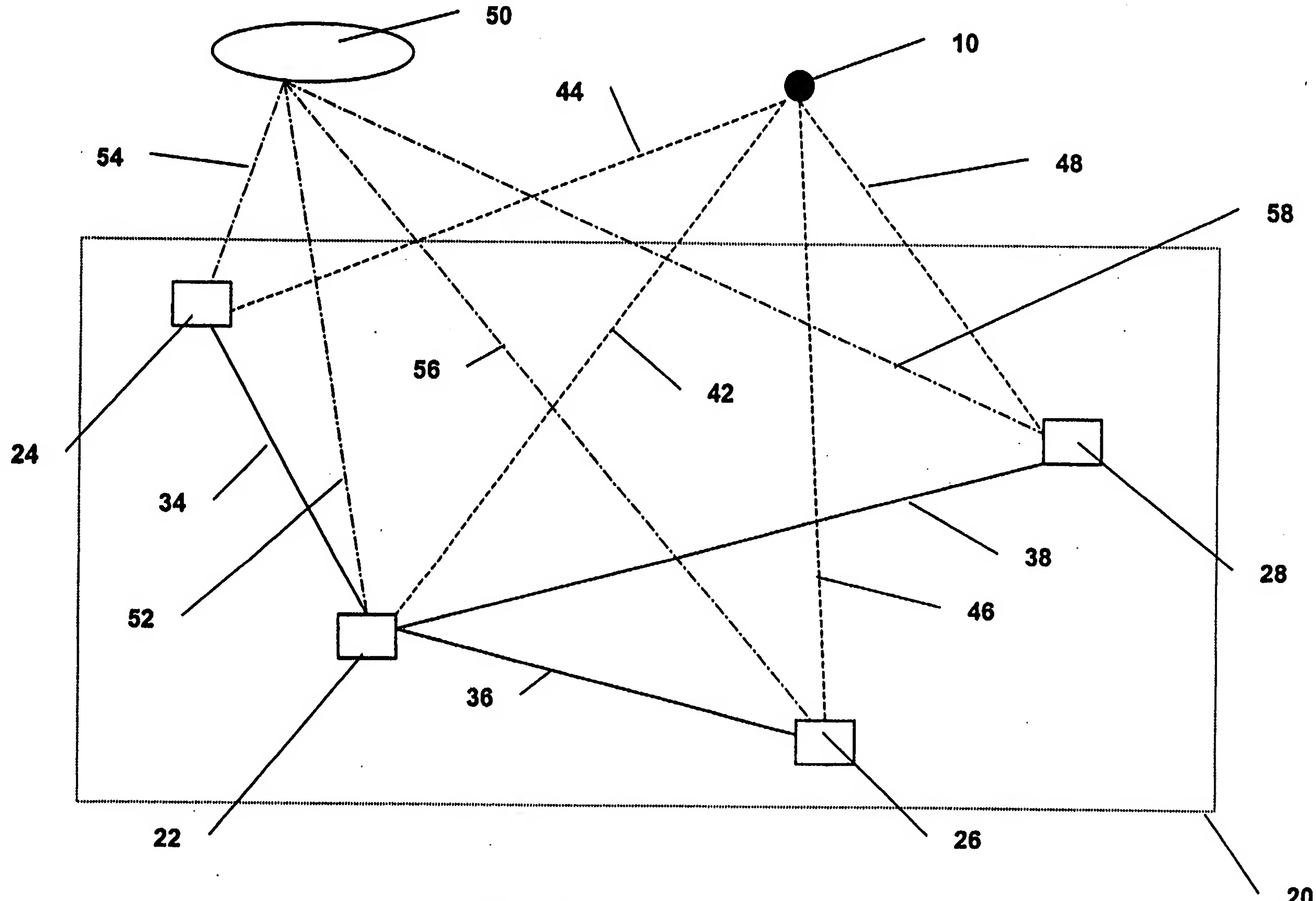

Fig. 1

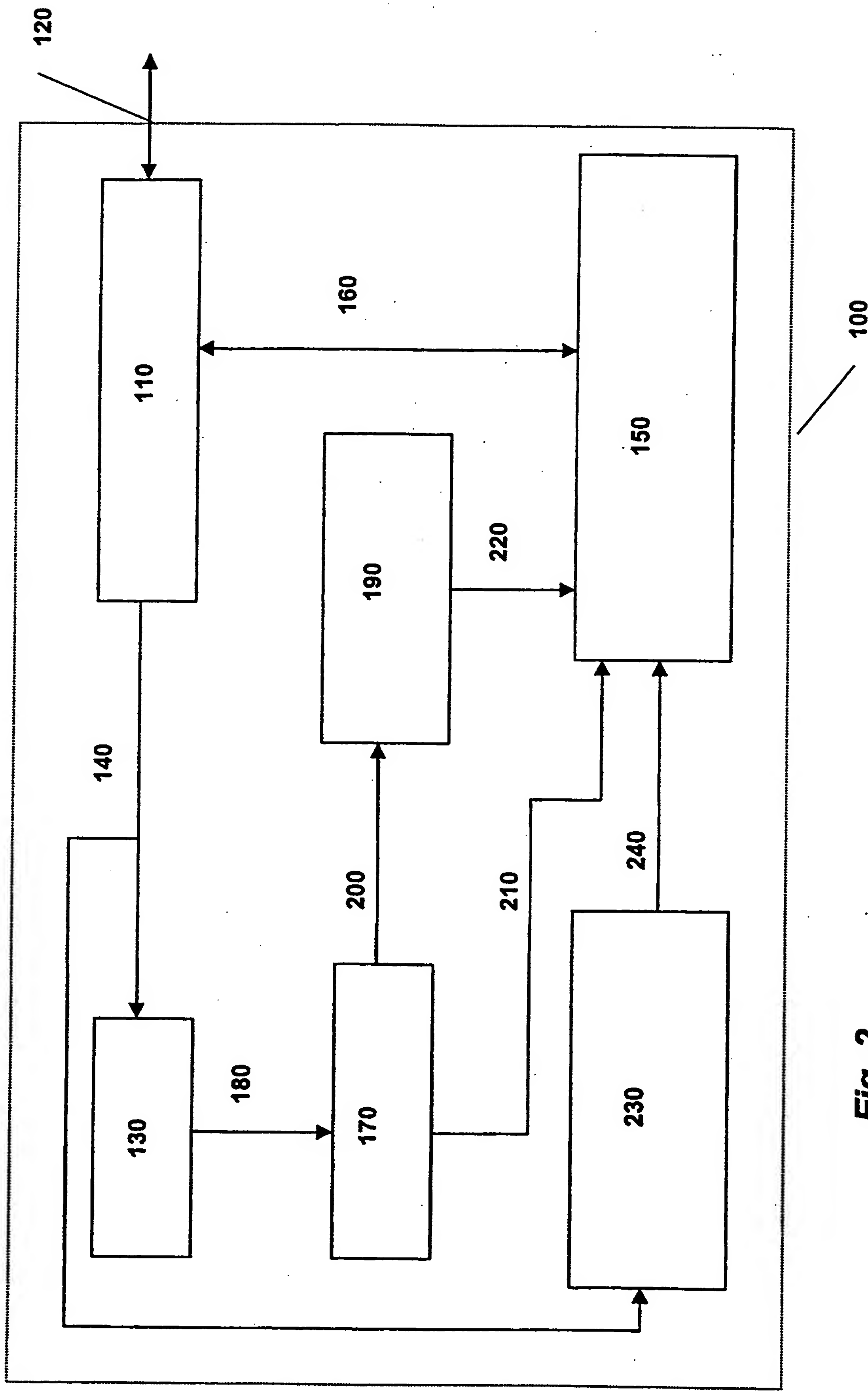

Fig. 2

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IMPROVEMENTS IN OR RELATING TO OBJECT LOCATION

The present invention relates to improvements in or relating to object location.

There are several techniques which can be utilised to locate the position of an object relative to a reference point, for example, the position of an aircraft with respect to one of a plurality of sites. One such technique is described in GB-B-2 250 154.

In GB-B-2 250 154, an object location system is described in which a master or reference receiver and a plurality of auxiliary receivers are precisely located with respect to one another for receiving signals from an object. The signals received at the receivers from the object comprise secondary surveillance radar (SSR) generated by the object. Each auxiliary receiver is synchronised with respect to a signal sent from the reference receiver so that a computation device associated with the reference receiver can determine the precise location of the object from signals received at all the receivers. In this system, the reference receiver and at least three other auxiliary receivers are required to generate four simultaneous equations which are solved by the computation device to provide the position of the object in three dimensions and the distance the object is from the reference receiver.

SSR is also used to effect synchronisation between the reference receiver site and the auxiliary receiver sites. Each auxiliary receiver site utilises an atomic clock for driving a free running counter which is read on reception of an SSR signal transmitted thereto from the reference receiver site. However, in the object location system described in GB-B-2 250 154, it is necessary for each auxiliary receiver site to have a direct 'line of sight'

with the master or reference receiver site so that the timing signals can be received.

Another technique for providing synchronisation between the reference receiver and the auxiliary receivers disclosed in GB-B-2 250 154 utilises the global positioning system (GPS), GPS being used at each receiver site to provide both accurate location and intersite clock synchronisation.

It is therefore an object of the present invention to provide an object location system which does not have the disadvantages mentioned above.

In accordance with one aspect of the present invention, there is provided a method of locating the position of an object which provides identifying signals, the method comprising the steps of:-

receiving the identifying signals from the object at a receiver array, the receiver array comprising a reference receiver site and at least three auxiliary receiver sites;

receiving signals from a global navigation system;

determining the time difference between receiving the identifying signals and the global navigation system signal at each receiver site;

transmitting data signals to the reference receiver site which are indicative of the determined time differences at each auxiliary receiver site; and

calculating the position of the object using the transmitted data signals and the time difference determined at the reference receiver site.

In accordance with another aspect of the present invention, there is provided apparatus for locating an object producing identifying signals, the apparatus comprising:-

a receiver array comprising a reference receiver site and at least three auxiliary receiver sites;

first receiver means at each receiver site for receiving the identifying signals from the object;

second receiver means at each receiver site for receiving signals from a global navigation system;

processing means at each receiver site for receiving signals from the first and second receiver means and for providing a time difference measurement from the signals; and

control means at the reference receiver site for receiving data signals from the auxiliary receiver sites indicative of the time difference measurement signals determined thereat, and for processing the data signals together with the time difference measurement from the reference receiver site to provide a determination of the location of the object.

For a better understanding of the present invention, reference will now be made, by way of example only, to the accompanying drawings in which:-

Figure 1 illustrates a schematic diagram of an object location system in accordance with the present invention; and

Figure 2 illustrates a block diagram of a receiver site in the object location system of Figure 1.

Although the present invention will be described with reference to height location of an aircraft, it will readily be appreciated that the invention can be utilised to determine the location of any object which produces an identifying signal.

Moreover, it will be appreciated that although the present invention will be described using the global positioning system (GPS), any global navigation system and augmentations, for example, global navigation satellite systems (GNSS), can be implemented.

In Figure 1, an object location system in accordance with the present invention is shown schematically. The position of an object 10, for example, an aircraft, is to be determined using a receiver array 20 indicated by dotted lines. Although the receiver array is shown having a rectangular configuration, this is not essential to the invention and the receiver array may comprise any suitable configuration. An optimum receiver geometry may be determined for aircraft concentrated within a specified volume of space. The optimum geometry corresponds to the combination of minimum height vector, defining the relationship between time measurement error and object positional error.

The aircraft 10 includes a secondary surveillance radar (SSR) system which can be interrogated by a signal from the ground, namely, from a separate interrogator (not shown) or from one of the receiver sites 22, 24, 26, 28 in the array 20 to produce an identifying signal for the aircraft 10. Alternatively, the SSR can transmit an identifying signal as a series of pulses. It will be appreciated that the present invention only requires that the aircraft provide some form of identifying signal and the form of the signal is immaterial.

The receiver array 20 comprises four receiver sites 22, 24, 26, 28. This is the minimum number of receiver sites which are required to determine the location of an aircraft. It may be necessary to use more than four receiver sites to maintain adequate coverage and positional accuracy over an extended volume of space. In the array 20, receiver site 22 is designated as a reference receiver site and the other receiver sites 24, 26, 28 as auxiliary receiver sites, but it is to be noted that any of the receiver sites could be designated as a reference receiver site.

Reference receiver site 22 is connected to the auxiliary receiver sites 24, 26, 28 by respective data links 34, 36, 38 as shown. The data links 34,

36, 38 transfer data between the reference site and the auxiliary sites as will be described in more detail later.

Each receiver site 22, 24, 26, 28 in the array 20 receives the signal from the aircraft 10 as illustrated by dotted lines 42, 44, 46, 48 respectively. It will be appreciated that the time it takes for the signal to reach each receiver site 22, 24, 26, 28 is different due to the differences in location of each site. Each receiver site 22, 24, 26, 28 also receives a global positioning system (GPS) signal from a GPS satellite 50 as indicated by chain lines 52, 54, 56, 58 respectively.

Referring now also to Figure 2, a receiver site 100 is shown in the form of a block diagram. Any one of receiver sites 22, 24, 26, 28 shown in Figure 1 may comprise receiver site 100. At receiver site 100, there is provided a communications interface 110 for providing a data link 120 with each of the auxiliary receiver sites 24, 26, 28, if the receiver site is the reference site 22, or with the reference receiver site 22 if the receiver site is an auxiliary receiver site 24, 26, 28. For simplicity, the receiver site 100 will be described as being an auxiliary receiver site. The communications interface 110 is connected to receive control signals from the reference receiver site 22 along the data link 120 and also to transmit data to the reference receiver site 22. The communications interface 110 is connected to a GPS receiver 130 via a link 140 and also to a measurement control system 150 via a link 160. Link 140 comprises a uni-directional link and operates to transmit an enable signal for the GPS receiver 130 from the reference receiver site 22. Link 120 comprises a bi-directional link for both receiving data from and transmitting data to the reference receiver site 22.

GPS receiver 130 is connected to a high precision clock oscillator 170 by connection 180 for supplying a signal indicative of a particular instant in time to the clock oscillator 170 when enabled by the enable signal received

from the reference receiver 22. The clock oscillator 170 is connected to a time interval counter 190 via connection 200 and also to the measurement control system 150 via connection 210. Time interval counter 190 is connected to the measurement control system 150 via a connection 220.

The receiver site 100 also comprises a SSR receiver 230 for receiving SSR signals from the aircraft 10. The SSR receiver 230 is connected to the measurement control system 150 via connection 240, and also connected to link 140 to receive an enable signal from the reference receiver 22 as shown.

The operation of the object location system in accordance with the present invention will now be described in more detail.

The reference receiver site 22 transmits a signal along data links 34, 36, 38 to each of the auxiliary receiver sites 24, 26, 28 which effectively instructs each auxiliary receiver site to initiate measurement of the time for the SSR signal from the aircraft 10 to reach that receiver site. The signal on each data link 34, 36, 38 enters each auxiliary receiver site 24, 26, 28 on data link 120, into the communications interface 110 and onto the GPS receiver 130 and SSR receiver 230 via link 140 and onto measurement control system 150 via link 160. The GPS receiver 130 supplies a signal to the high precision clock oscillator 170 which in turn initiates time interval counter 190 and measurement control system 150 via connections 200 and 210 respectively. The clock oscillator 170 provides trigger pulses on connection 200 to the time interval counter 190 which operates to generate count indicative of the time from initiation and supplies it to the measurement control system 150 on connection 220. The measurement control system 150 also receives trigger pulses on connection 210 from the clock oscillator 170. When a signal is received by the SSR receiver 230 from the aircraft 10, the measurement control system 150 receives a signal on connection 240 and the time currently on the time interval counter 190 is stored in the measurement

control system 150. The measurement control system 150 determines a time difference measurement between the signals received from the SSR receiver 230 and those received from the time interval counter 140, the time difference measurement being sent to the reference receiver site 22 via link 160, communications interface 110 and data link 120.

The GPS signal comprises a phase-locked signal which is used to control the high precision clock oscillator 170 to counteract frequency drift and to provide long term stability.

At the reference receiver site 22, data signals from each of the auxiliary receiver sites 24, 26, 28 relating to the time difference measurements between the GPS signal and the SSR signal received at each site are received. The measurement control system of the reference receiver site 22 processes the data signals from auxiliary receiver sites 24, 26, 28 and the time difference measurement obtained at the reference receiver site itself to provide an indication of the location of the aircraft 10 relative to the reference receiver site 22.

As the method of the present invention utilises GPS to establish an accurate reference timing, there is no requirement for there to be a 'line of sight' between the receiver sites in the receiver array. The receiver sites may be chosen to correspond to existing air traffic control centres. Each receiver may also comprise a mobile installation which facilitates re-configuration of the receiver array in accordance with changes in aircraft routing.

CLAIMS:

1. A method of locating the position of an object which provides identifying signals, the method comprising the steps of:-

receiving the identifying signals from the object at a receiver array, the receiver array comprising a reference receiver site and at least three auxiliary receiver sites;

receiving signals from a global navigation system;

determining the time difference between receiving the identifying signals and the global navigation system signal at each receiver site;

transmitting data signals to the reference receiver site which are indicative of the determined time differences at each auxiliary receiver site; and

calculating the position of the object using the transmitted data signals and the time difference determined at the reference receiver site.

2. Apparatus for locating an object producing identifying signals, the apparatus comprising:-

a receiver array comprising a reference receiver site and at least three auxiliary receiver sites;

first receiver means at each receiver site for receiving the identifying signals from the object;

second receiver means at each receiver site for receiving signals from a global navigation system;

processing means at each receiver site for receiving signals from the first and second receiver means and for providing a time difference measurement from the signals; and

control means at the reference receiver site for receiving data signals from the auxiliary receiver sites indicative of the time difference measurement signals determined thereat, and for processing the data signals together with the time difference measurement from the reference receiver site to provide a determination of the location of the object.

3. Apparatus according to claim 2, wherein the identifying signals from the object comprise secondary surveillance radar (SSR) signals and the first receiver means comprises a SSR receiver.

4. Apparatus according to claim 2 or 3, wherein the processing means comprises a high precision clock oscillator, a time interval counter and a measurement control system.

5. Apparatus according to any one of claims 2 to 4, wherein the processing means includes a communications interface for interfacing between each auxiliary receiver site and the reference receiver site.

6. Apparatus substantially as hereinbefore described with reference to the accompanying drawings.

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Application No:	GB 9911135.3	**Examiner:**	Dr E.P. Plummer
Claims searched:	all	**Date of search:**	23 December 1999

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.Q): H4D (DPBC, DPX, DAB, DPAB, DPAC, DPAX, DPX)

Int Cl (Ed.6): G01S

Other: Online: WPI, EPODOC, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X Y	GB2310098A	WESBY whole document	1,2,4,5; 3,6
X Y	GB2283142A	THOMSON whole document	1,2,4,5; 3,6
Y	GB2250154A	ROKE MANOR whole document	1-6
X Y	EP0733912A2	GENERAL ELECTRIC whole document	1,2,4,5; 3,6
Y	EP0120520A1	NV PHILIPS whole document	1,2,4,5
Y	EP0006594A1	SIEMENS whole document	1,2,4,5
Y	US5382958	MOTOROLA whole document	1-6

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
&	Member of the same patent family		

Application No: GB 9911135.3
Claims searched: all

Examiner: Dr E.P. Plummer
Date of search: 23 December 1999

Category	Identity of document and relevant passage	Relevant to claims
X Y	US5317323 E-SYSTEMS whole document	1,2,4,5; 3,6
Y	US4866450 SUNDSTRAND whole document	1-6
Y	Radar 92, IEE conference publication no.365, pages 250-253: DC Rickard et al: The development of a prototype aircraft monitoring unit utilising SSR-based difference in time of arrival technique	1-6
X	The Marconi Review vol.XLVI no.228 1983 pages 1-17: DE Rice: Height measurement by quadrilateration. Note in particular pages 7 and 8.	1-6

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Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.